THE ROLE OF ASYMMETRIC INFORMATION AMONG INVESTORS IN THE FOREIGN EXCHANGE MARKET

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ABSTRACT

This paper posits asymmetric information as the missing link between the currency demands of investors and changes in the exchange rate. A theoretical model demonstrates that changes in the exchange rate and currency demand are positively correlated for well-informed investors and negatively correlated for less well-informed investors, results consistent with stylized facts from the empirical literature. These theoretical findings are supported empirically using a new data set from the Israeli foreign exchange market. The empirical analysis indicates that a one million dollar larger purchase than sales by well-informed financial investors induces an increase of 0.060 per cent in the Israeli Sheqel/Dollar exchange rate over a one month period. A similar net flow from less well-informed investors results in a 0.046 per cent decrease in the exchange rate. Copyright © 2008 John Wiley & Sons, Ltd.

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1. INTRODUCTION

It is well established in the exchange rate literature that macroeconomic variables such as the money supply and GDP have very little effect on exchange rates, especially in the short run. Flood and Rose (1995) demonstrate this disconnect between macroeconomic fundamentals and the exchange rate, noting that volatility in money and output does not appear to vary significantly during regimes of fixed and floating exchange rates. Their conclusion is that most critical determinants of exchange rate volatility are not macroeconomic and that research on this topic should concentrate on more microeconomic details. The approach used in the current paper, commonly referred to as market microstructure, emphasizes microeconomic details in the foreign exchange market.

This study contributes to the literature on exchange rates and market microstructure in three ways. First, the theoretical model utilizes informational heterogeneity among investors and permits an analysis of the foreign exchange market as the amount of asymmetric information in the market changes. Second, I demonstrate theoretically and empirically that there is a correlation between a change in the exchange rate and the change in currency holdings of investors, which varies with investor information. Finally, the empirical analysis in this paper is the first study of disaggregated customer order flow data from the Israeli currency market. Israel is an emerging market that is distinct from the predominantly developed countries examined in the literature.

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In the following section, I present some background on exchange rates and their markets, as well as a brief discussion of the relevant literature. Section 3 develops a two-country model of asymmetrically informed investors that is consistent with the stylized facts. Section 4 analyses the Israeli foreign exchange market for empirical support of the theoretical model. Section 5 concludes and discusses extensions to this research.

2. BACKGROUND AND LITERATURE

The foreign exchange market is composed of three major players: dealers, brokers, and customers. Customers are investors and they are the ultimate end-users of currency. They trigger the initial currency exchange by placing buy or sell orders with dealers. Dealers are intermediaries in the market and they quote prices, provide liquidity, and attempt to profit (and take risks) by holding positions during the day. At the end of their trading session, dealers try to revert back to their initial inventory position and they do this by offering lucrative prices to customers. The third group of players in the market, brokers, acts as message boards by giving dealers the option of an opaque interdealer trade.

Order flow is a microstructure term used to describe the net trades of investors. It corresponds to the difference between purchases and sales of investors in the market. Using a microstructure approach, Evans and Lyons (2002) find that interdealer order flow explains 60 per cent of changes in the exchange rate. Their model takes incoming customer order flows as exogenous and focuses on the trades between dealers. Since it is known that customer order flows trigger the interdealer trade in the first place, a natural direction for the literature has been toward understanding customer order flows. As more and more order flow data have become available for analysis, the importance of customer trades for explaining high-frequency changes in the exchange rate has become apparent. In particular, a specific correlation exists between net flows from different types of customers in the market and observed changes in the exchange rate. Various empirical studies (Marsh and O’Rourke, 2005; Bjonnes et al., 2005; Fan and Lyons, 2003) demonstrate that, while order flow from financial customers has a positive correlation with the direction of change in the price of the exchange rate, order flow from non-financial customers has a negative correlation. As stated above, it is this customer (or investor) heterogeneity that is explored theoretically and empirically in this paper.

Wu (2006) uses a data set consisting all of the daily transactions in the Brazilian foreign exchange market spanning the four year time period between 1999 and 2003. As in the present study, Wu (2006) investigates the foreign exchange market in an emerging economy. Wu finds that a one per cent depreciation in the currency decreases the financial customer flow by $111 million and the commercial flow by $46 million.

There are two other studies in the literature, which offer theoretical models to explain the relationship between flows from different customer types and changes in the exchange rate. Evans and Lyons (2006) model three different types of customers; long-term investors, short-term investors, and importers/exporters. Heterogeneity among investors in their model arises mainly from the horizon of their investment and also there is no hierarchical information set-up in their model. In their empirical work, the authors use Citibank data to compare simulated results from their model with empirical estimates. They find that customer flows forecast returns because they are correlated with the future market-wide information flow that dealers use to revise their prices. They also find that correlations are higher at lower frequencies. Osler (2006) introduces a simple model where the two types of agents in the market are investors and importers/exporters, but does not model the information asymmetry in the foreign exchange market. Her results suggest that the positive correlation between financial demand and exchange rates is due to the short-run dominance of financial shocks relative to commercial shocks.

3. THEORETICAL MODEL

3.1. Model overview

Unlike the models in the literature, the theoretical model presented below emphasizes the importance of hierarchical information asymmetry in the foreign exchange market. All investors observe a common,
noisy (public) signal about the future value of fundamentals, such as money supply. A portion of these investors are ‘informed’ in the sense that they also receive a noisy private signal about future fundamentals in addition to their public signal. Every period investors decide how much to invest in domestic bonds, foreign bonds, and their non-asset income. I assume that this non-asset income depends on exchange rates, thus creating some hedging demand in the foreign exchange market. Investors also make use of the exchange rate as a signal since it carries information about future fundamentals, but this is an imperfect signal due to unobserved hedge trades in the market.

When there is a positive shock to future fundamentals, informed investors observe this information through their private signal and increase their currency holdings. The counterpart of this trade is taken by less-informed investors. Since better future fundamentals cause an increase in the exchange rate, the model generates a positive correlation between the change in currency holdings of financial (informed) investors and the change in exchange rate, as well as a negative correlation for the change in currency holdings of non-financial (less-informed) investors.

3.2. Model detail

The three building blocks of a two-country monetary model of exchange rate determination are money market equilibrium, purchasing power parity, and interest rate parity. I begin by assuming that purchasing power parity holds using

\[ p_t = p_t^* + s_t \]  

where \( p_t \) is the log of the price level in the country and \( s_t \) is the exchange rate. Foreign country variables are indicated with an asterisk.

There is a continuum of investors in both countries and they are distributed on the interval \([0,1]\). I assume a myopic agent set-up where agents live for two periods and make only one investment decision. This overlapping generations’ design simplifies the solution substantially. Investors are identical in the sense that they have the same utility function and they know that the exchange rate depends on expectations of future fundamentals. Differences among investors arise from the signals that they receive about the value of future fundamentals. All investors receive a common public signal about the value of future fundamentals, but a proportion of these investors also receive a private signal about this value. Before I introduce information asymmetry into the model, I describe the general solution of investors’ demand for foreign currency.

Investors in both countries can invest in money of their own country, bonds of the home country for a return of \( i_t \), bonds of the foreign country for a return of \( i_t^* \), and in some type of production with a fixed return. I assume that the home country is large and the foreign country is infinitesimally small. This allows the bond market equilibrium to be entirely determined by investors in the large home country. It is also assumed that money supply in the home country is constant, whereas money supply in the foreign country is stochastic. For ease, I assume a constant price level in the home country so that the interest rate in the home country is constant.

At time \( t \), investor \( i \) is given a fixed endowment \( w_t^i \). At time \( t + 1 \), this investor receives the return on his investments, as well as non-asset income from investing in production. This production is assumed to depend on the exchange rate as well as on real money holdings of investor \( i \), \( m_t \). Thus, the production function is expressed as \( f(m_t^i) = \kappa_t s_{t+1} - \mu_t^i(\ln(m_t^i) - 1)/z \) for \( z > 0 \). The coefficient \( \kappa_t^i \) is the exchange rate exposure variable. Since investor \( i \)'s production depends on the exchange rate, the investor will want to hedge himself, and this hedge against non-asset income adds to the demand in the foreign exchange market. An investor’s hedge demand changes every period and it is only known by the individual investor.

Investors trade competitively in the market based on their information. They have constant absolute risk aversion preferences denoted with Arrow–Pratt coefficient of absolute risk aversion, \( \gamma \). Agent \( i \) maximizes his expected discounted future utility conditional on information known at \( t \), \( F_t^i \), and his budget constraint.
The maximization problem can be expressed as
\[
\max \quad -E_i [e^{-\gamma c_{i,t+1}} | F_t^i] \\
\text{ s. t. } \quad c_{i,t+1}^i = (1 + i_t)w_{i,t}^i + (s_{i,t+1} - s_t - i_t^* - i_t)B_t^i - i_t\mu_t^i + f(p_t^i)
\]
where \(w_{i,t}^i\) is wealth at the start of period \(t\), \(B_t^i\) is the amount invested in foreign bonds, and \(s_{i,t+1} - s_t + i_t^* - i_t\) is the log-linearized excess return on investing in foreign bonds. Investor \(i\) maximizes his \(t + 1\) consumption by investing in domestic and foreign bonds, as well as by choosing how much to invest in his non-asset income. The constant absolute risk aversion assumption enables investors to set their maximization decisions independent of their wealth. Assuming that the exchange rate is normally distributed, this implies income. The constant absolute risk aversion assumption enables investors to set their maximization by investing in domestic and foreign bonds, as well as by choosing how much to invest in his non-asset income. The constant absolute risk aversion assumption enables investors to set their maximization decisions independent of their wealth. Assuming that the exchange rate is normally distributed, this implies that the equilibrium exchange rate is independent of the wealth distribution of investors as well as the level of aggregate wealth. Investor \(i\) chooses the optimal amount of foreign bonds to hold and the first-order condition is
\[
s_t = E_i(s_{t+1}) - i_t + i_t^* - \gamma \sigma_{ij}^2 (B_t^i + b_t^i)
\]
where \(\sigma_{ij}^2 = \text{var}(s_{t+1})\) is the conditional variance of next period’s exchange rate and \(b_t^i\) is the hedge due to the exchange rate exposure of non-asset income, \(b_t^i = k_t^i\). In addition to optimal bond holdings, the first-order conditions from both domestic and foreign investors’ optimal money holdings are
\[
m_t - p_t = -x_i
\]
\[
m_t^* - p_t^* = -x_i^*
\]
where \(m_t\) and \(i_t\) are logs of money supply and interest rate, respectively. These equations coupled with purchasing power parity relate the exchange rate to market fundamentals. I specify the interest differential in terms of the exchange rate and fundamentals to obtain \(i_t - i_t^* = 1/\gamma(s_t - f_t)\), where the fundamentals are defined as \(f_t = (m_t - m_t^*)\).

Combining equations (3) and (4), investor \(i\)’s foreign bond demand can be expressed as
\[
B_t^i = \frac{E_i(s_{t+1}) - s_t + i_t^* - i_t}{\gamma \sigma_{ij}^2} - b_t^i
\]
where the first term is the investment demand that depends on excess return on investing in foreign bonds as well as risk aversion in the denominator. The second term represents the hedging demand against currency exposure in the investor’s non-asset income.

Hedging demand emerging from the exchange rate exposure variable is assumed to be composed of an average term and an idiosyncratic term, \(b_t^i = b_t + e_t^i\). I assume that, even though every investor observes their own exposure term, the average hedging demand is unobservable to any of the investors. By adding an unobservable noisy term to the exchange rate equation, this assumption prevents the exchange rate from revealing all the information in the market to the investors. Even though investors do not observe the average term, I assume that they know the autoregressive process it follows, \(b_t = \rho_t b_{t-1} + e_t^p\), where \(e_t^p \sim N(0, \sigma_b^2)\).

Since investors are the end-users in the market, the aggregate foreign bond demand of the traders in the model should sum to zero. Thus, the condition that characterizes the market equilibrium is \(\int B_t^i \, di = 0\). Applying this market equilibrium condition to (5) yields
\[
E_i(s_{t+1}) - s_t - i_t^* + \gamma b_t \sigma_{ij}^2
\]
where \(E_i\) is the average expectation across all investors. Note that the idiosyncratic terms are zero when integrated out over all investors and the risk-premium term, \(\gamma b_t \sigma_{ij}^2\), depends on the average hedging demand as well as the average conditional variance, represented by \(\sigma_{ij}^2\). Since investors are risk averse, they require a premium to hold foreign bonds when they do not have perfect information about tomorrow’s
exchange rate. Using equation (6) and the definition of fundamentals, the equilibrium exchange rate is given by

$$s_t = \sum_{k=0}^{\infty} \left( \frac{\alpha}{1+\alpha} \right)^k E_t^i (f_{t+k} - \alpha\gamma \sigma_t^2 b_{t+k})$$  

(7)

where $E_t^i$ are expectations of order $k>1$, defined as $E_t^i(s_{t+k}) = \int_0^1 E_t^i(E_t^i(s_{t+k-1})) \, di$ with $E_t^i(s_{t+1}) = E_t(s_{t+1})$ and $E_0^i(s_t) = s_t$.

Equation (7) indicates that the exchange rate at time $t$ depends on the fundamentals at time $t$, the average expectation of future fundamentals, and future risk premia. Note that with dispersed informations, the law of iterated expectations does not apply to average expectations and $E_t^i E_{t+1}(s_{t+2}) \neq E_t(s_{t+2})$. The expectation of other investors’ expectations matter. By focusing on a myopic set-up, I circumvent this infinite regress problem.

3.3. Information structure

In addition to observing all past and current values of fundamentals, all investors in the market receive a noisy public signal about the future value of fundamentals. Asymmetric information arises from the fact that a proportion of investors also receive a private signal about the future value of fundamentals. Both signals are noisy; they do not fully disclose the future value of the fundamentals. I use $\omega$ to denote the proportion of investors who are (relatively) ‘uninformed’ because they receive only the public signal. The remaining proportion of investors, $1-\omega$, are classified as ‘informed’ investors. Note that changing the ratio of informed investors to uninformed investors in the economy is equivalent to choosing how much private information exists in the market. When $\omega = 1$, every investor in the economy is receiving only the public signal so all are uninformed, and when $\omega = 0$, every investors is receiving both of the signals so all of them are informed.

Assume that the fundamentals in the economy are governed by the process $f_t = D(L)\epsilon^i_t$, where $\epsilon^i_t \sim N(0,\sigma^2_t)$ and $D(L) = d_1 + d_2 L + d_3 L^2 + \cdots$. I denote the noisy public signal received by all investors as $z_t$ and the noisy private signal received by informed investor $i$ as $v^i_t$. These signals carry information about the value of the fundamental $T$ periods ahead, $f_{t+T}$. Let $u_t$ denote the future value of fundamentals in the economy, $u_t = f_{t+T}$. This notation makes it easier to compare the two separate effects of current and future fundamentals on the exchange rate. In the economy, let the noisy public signal be composed of two pieces: $z_t = u_t + \epsilon^o_t$, where $w^o_t = \rho_w \epsilon^{o-1}_t + \epsilon^o_t$ and $\epsilon^o_t \sim N(0,\sigma^2_o)$. The first term is the actual value of future fundamentals and the second, $w^o_t$, is a persistent term that I assume follows an autoregressive process with $\rho_w < 1$. The error term, $\epsilon^o_t$, is independent from the value of future fundamentals and it is unknown to investors at time $t$. In this set-up, the public signal does not reveal the exact value of future fundamentals to the investors. The structure of the noisy private signal is given by $v^i_t = u_t + \epsilon^i_t$, where $\epsilon^i_t \sim N(0,\sigma^2_i)$ and the error term of the signal is independent of $u_t$ and other investors’ signals. By the law of large numbers, the average signal received by informed investors is $u_t$, namely $\int_{-\infty}^1 v^i_t \, di = u_t$.

As mentioned previously, there are two types of investors in the economy that differ in the amount of information they possess. Let $F^i_t = \{s_t, f_t, z_t, v^i_t : \tau < t + 1\}$ be the informed investors’ information set at time $t$ and $F^o_t = \{s_t, f_t, z_t : \tau < t + 1\}$ be the uninformed investors’ information set at time $t$. Given this information structure, observing the equilibrium exchange rate, $s_t$, and current fundamentals, $f_t$, does not reveal independent realizations of future fundamentals, $u_t$ and the average hedge demand, $b_t$, to the investors. They learn about only a combination of those state variables, so that there is no perfect information revelation.

3.4. The equilibrium exchange rate

Using $i_t - i^*_t = (1/\alpha)(s_t - f_t)$, equation (6) can be rewritten to show that the equilibrium exchange rate depends on the first-order average market expectation as well as on current fundamentals and non-fundamentals:

$$s_t = \frac{1}{1+\alpha} f_t + \frac{\alpha}{1+\alpha} E_t(s_{t+1}) - \frac{\alpha}{1+\alpha} \gamma b_t \sigma^2_i$$  

(8)
In order to demonstrate the model’s results in an analytical and more tractable fashion, I analyse the myopic case where only time \( t+1 \) variables matter and values of fundamentals from time \( t+2 \) onward do not enter the equation. The solution to the more general model results in the loss of tractability of equilibrium equations. Since customer order flow is also high frequency in nature, the inclusion of longer-period analysis is not as beneficial as tractability to the model. In the myopic case, only tomorrow’s fundamentals matter, which implies \( u_t = f_{t+1} \). Thus, fundamentals of later dates do not enter the exchange rate equation. Using equation (7), the exchange rate formed by the one-period ahead expectation of the investors is given by

\[
s_t = \frac{1}{1 + \alpha} [f_t - \alpha \gamma \sigma^2 b] + \frac{1}{1 + \alpha} \left( \frac{\alpha}{1 + \alpha} \right) \mathbb{E}[f_{t+1} - \alpha \gamma \sigma^2 b_{t+1}]
\]

In what follows, I assume \( b_t \) and \( f_t \) to be i.i.d. and \( \rho_z = 0.3 \). This makes the analysis more tractable without altering the results. The first step in solving the model is to analyse individual investor decisions by information type, which is then used to determine the average expectation of tomorrow’s fundamentals, \( \mathbb{E}(f_{t+1}) \).

Since average expectation of tomorrow’s fundamentals will be determined by the signals received by investors in the economy, I conjecture that the equilibrium exchange rate will depend on today’s fundamentals, public signal in the economy, tomorrow’s fundamentals and the total hedge demand in the economy:

\[
s_t = \frac{1}{1 + \alpha} f_t + \lambda_u u_t + \lambda_z z_t - \lambda_b b_t
\]

I make use of the method of undetermined coefficients to solve for the coefficients of future fundamentals, public signal and aggregate hedge demand in equilibrium.

**Expectations of investors**

All of the uninformed investors have the same information set. There are three possible sources of their information about future fundamentals: the common public signal, the knowledge of distribution of fundamentals, and the observed exchange rate. Uninformed investors’ expectations of tomorrow’s fundamentals are a weighted average of all of these signals.

Rewriting the conjecture stated above, I show what the uninformed investors learn from observing the exchange rate signal:

\[
\left( s_t - \frac{1}{1 + \alpha} f_t - \lambda_z z_t \right) \frac{1}{\lambda_u} = u_t + \frac{\lambda_b}{\lambda_u} b_t
\]

where the left-hand side of equation (11) is what is observed by the investors (the signal), and the right-hand side is not directly observed. The variance of the error term of the exchange rate signal is \( (\lambda_b/\lambda_u)^2 \sigma^2_b \). This also means that precision of the exchange rate signal depends on \( \lambda_b/\lambda_u \), which is endogenous in the model.

For an uninformed investor, the weighted average of the three signals can be expressed as

\[
E^i(u_t) = \frac{\beta^u 1}{\lambda_u} \left( s_t - \frac{1}{1 + \alpha} f_t - \lambda_z z_t \right) + \beta^z z_t + \beta^b b_t
\]

where the \( \beta \)'s capture the precision of the corresponding signals, that is, \( \beta^u = 1/\sigma^2_u \), \( \beta^z = 1/\sigma^2_z \) and \( \beta^b = 1/(\lambda_b/\lambda_u)^2 \sigma^2_b \). Every signal is weighted by dividing its own precision by the overall precision for the uninformed investors, namely \( d = 1/\text{var}(u_t) = \beta^u + \beta^z + \beta^b \).

For an informed investor, the weighted average of the signals has an additional term since every informed investor receives their own private signal:

\[
E^i(u_t) = \frac{\beta^u 1}{\lambda_u} \left( s_t - \frac{1}{1 + \alpha} f_t - \lambda_z z_t \right) + \beta^z z_t + \beta^b v_t
\]
where the additional precision term is defined as $b^v = 1/\sigma^2_v$ and $D = 1/\text{var}(u_t) = \beta^v + \beta^z + \beta^s + \beta^u$ is the overall precision of informed investors’ signals.

**The coefficients**

I integrate the expectations above over the continuum of investors to find the average expectation of tomorrow’s fundamentals:

$$
\mathbb{E}_t(u_t) = \frac{1}{1 - \omega} \left( \frac{\beta^u}{\sigma^2_u} \left( s_t - \frac{1}{1 + \zeta^2} f_t - \lambda_z z_t \right) + \beta^z z_t \right) + \frac{\beta^u u_t}{D} (1 - \omega)
$$

$$
+ \omega \frac{\beta^z z_t + \beta^u \left( s_t - \frac{1}{1 + \zeta^2} f_t - \lambda_z z_t \right)}{\sigma^2_z}
$$

(14)

It is apparent from equation (14) that the expectation of tomorrow’s fundamentals depends on the ratio of informed to uninformed investors in the market. Also note that the errors of the private signals sum to zero when integrated over a continuum of informed investors, which is how the actual value of future fundamentals enters the exchange rate in equilibrium. Substituting this average expectation back into equation (9) solves for the coefficients of the conjectured exchange rate equation above:

$$
\sigma^2_z = \frac{1}{1 + \alpha^2} f_t + \lambda_z u_t + \lambda_z z_t - \lambda_b b_t
$$

(15)

where

$$
\lambda_u = \frac{\alpha}{(1 + \alpha)^2} \left[ \left( \frac{\omega}{\sigma^2} + \frac{1 - \omega}{D} \right) \beta^v + \left( \frac{1 - \omega}{D} \right) \beta^u \right]
$$

$$
\lambda_z = \frac{\alpha}{(1 + \alpha)^2} \left( \frac{\omega}{\sigma^2} + \frac{1 - \omega}{D} \right) \beta^v
$$

$$
\lambda_b = \frac{\alpha}{1 + \alpha^2} \left[ 1 + \left( \frac{\omega}{\sigma^2} + \frac{1 - \omega}{D} \right) \left( \frac{D}{1 - \omega} \right) \beta^v \right]
$$

Since $\lambda_b/\lambda_u$ is decided endogenously in this system of equations, I solve a fixed point problem to reach the actual values of the coefficients. Looking at each coefficient closely, it is observed that all the $\lambda$’s are influenced by the weighted ratio of informed to uninformed investors, $\omega/d + (1 - \omega)/D$.

One of the primary contributions of this theoretical model is that it allows for the analysis of how information asymmetry in the economy affects the equilibrium exchange rate. Figures 1–3 show how the coefficients change with respect to the information ratio in the economy. Figure 1 shows that as $\omega \to 1$, the private information in the economy disappears and, thus, the effect of the public signal shocks, $\lambda_z$, moves toward its maximum. When I investigate the coefficient of the future fundamentals, $\lambda_u$, Figure 2 shows that the effect of the actual future fundamentals on the exchange rate peaks because almost all of the investors are receiving a private information signal as $\omega \to 0$. The most interesting result comes from the coefficient on hedge demands, $\lambda_b$. There is still confusion about the cause of the change in the economy when $\omega = 0$ and, thus, the hedge demand coefficient is effective. Since investors do not necessarily know if a change in the exchange rate today is a result of a change in hedge demand or a change in tomorrow’s fundamentals, they mistakenly (but rationally) assign weight to both sources. Finally, Figure 3 reveals that the coefficient increases slightly as there is less private information in the economy, but it peaks as the ratio of informed to uninformed investors in the market diminishes. As $\omega \to 1$, every investor acquires the same public signal in the economy and, as a result, all investors can easily deduct the magnitude of the hedge demand after observing the foreign exchange price. This means there is no confusion and everyone has perfect information. Investors do not know the true value of the future fundamentals, but they know that true fundamentals do not influence the price of the exchange rate, only signals do. This is why the value of $\lambda_b$ drops to its minimum level as no investor in the economy receives any private information signal.
When $\lambda_u$, $\lambda_z$, and $\lambda_h$ are analysed all together, the coefficient on the private information signal, $\lambda_u$, peaks when every investor in the economy has private information, whereas the public information coefficient is at its minimum level, and the magnitude of the hedge demand coefficient is also weak compared with most of the other information ratio cases. As the private information in the economy diminishes, the importance of the public information coefficient picks up slowly, and so does the importance of the bond supply coefficient. When the economy is close to the no private information case, the importance of the public
information coefficient rises sharply, but the bond supply becomes transparent and its coefficients falls to its minimum level. Even in this myopic case, the amount by which each coefficient affects the exchange rate differs according to the distribution of information in the economy. At certain levels of information asymmetry, a public information signal can cause a larger change in the exchange rate than future fundamentals. I have also shown that there exist information levels where a shock to the aggregate hedge demand results in a large change in the exchange rate and, for a different amount of information, the effect of this shock to the foreign bond supply is relatively small.

3.5. Currency demand of investors

As discussed above, asymmetric information is important in determination of the equilibrium exchange rate. An equally important question is how this information structure affects the currency demand of investors in the market. Making use of the solution to the general model and the identity

\[ i_t/C_3 = (f_t/C_0)_{st}^{1/a}, \]

the demand for any investor \( i \) in the market is expressed as

\[ B_{it} = E_t(s_{t+1}) - s_t + (f_t - s_t)^{1/2} - b_t^i \]  \hspace{1cm} (16)

Utilizing the fact that \( E_t(s_{t+1}) = 1/(1 + \omega)E_t(u_t) \) and the definitions of distinct expectations of future fundamentals for informed and uninformed investors, the currency demand by both types of investors in the economy is characterized below.

Currency demand for uninformed investors

Making use of equations (12) and (16), the currency demand for an uninformed investor \( i \), \( B_{it}^{un} \), is expressed as

\[ B_{it}^{un} = \frac{\beta\beta^i(s_t - s_t)^f - \lambda^i z_t}{d} - s_t + (f_t - s_t)^{1/2} - b_t^i \]  \hspace{1cm} (17)

Substituting the definition for \( \lambda_u \) from equation (15) and rewriting equation (17) yields

\[ B_{it}^{un} = \left( \frac{f_t}{1 + \omega} - s_t \right) \left( \frac{1 + \omega}{\alpha} \right) \left[ 1 - \beta \phi \frac{D}{d(1 - \omega)} + \frac{1}{1 + \alpha d^2 \gamma^2} \phi \beta^i - b_t^i \right] \]  \hspace{1cm} (18)

where \( \phi \) represents the reciprocal of the multiplication factor, which is the magnification of shocks to equilibrium exchange rate due to asymmetric information. The multiplication factor is equal to

\[ \frac{1}{\phi} = 1 + \left( \frac{1 - \omega}{D} + \frac{\omega}{d} \right) \frac{\beta^i D}{\beta^i(1 - \omega)} \]  \hspace{1cm} (19)

Aggregating over all of the demand coming from uninformed investors,

\[ \int_0^\omega B_{it}^{un} di = \left( \frac{f_t}{1 + \omega} - s_t \right) \left( \frac{1 + \omega}{\alpha} \right) \left[ \omega - 1 + \phi \left( 1 + \frac{\beta^i}{\beta^i} \right) \right] \]  \hspace{1cm} (20)

+ \frac{\omega}{1 + \alpha d^2 \gamma^2} \phi \beta^i - \omega b_t

I find that currency demand has three components. The first two pieces capture the limit orders that are dependent on the exchange rate and common information (including the public signal). Note that asymmetric information in the economy enters this part through many variables such as the proportion of uninformed investors in the market, the precision of the exchange rate signal, and the reciprocal of the multiplication factor, which are themselves dependent on \( \omega \). The third piece is the private information and it is the hedge demand averaged over uninformed investors. Because of the law of large numbers, the private information portion can be expressed as the average hedge demand in the economy scaled by the percentage of uninformed investors in the market.
Currency demand for informed investors

Making use of equations (13) and (16), the currency demand for an informed investor $i$, $B_i^m$, is expressed as

$$B_i^m = \frac{1}{\gamma \sigma^2_i} \left[ (f_i - s_i) \frac{1}{1 + z} \frac{1}{\sigma^2_i} - s_i + (f_i - s_i) \frac{1}{1 + z} \right] - b_t^i$$

Aggregating over all of the demand of the informed investors,

$$\int_0^1 B_i^m \, di = \left( \frac{f_i}{1 + z} - s_i \right) \left( \frac{1}{\gamma \sigma^2_i} \right) \left[ 1 - \omega - \frac{\beta^*}{\beta^2} \right]$$

$$+ \left( \frac{1 - \omega}{1 + z} \right) \frac{\phi \beta^2}{\gamma \sigma^2_i} - \omega b_t$$

I find that currency demand has four components. The portion that captures the limit orders in equation (22) is similar to the first portion of equation (20) but weighted differently due to different investor ratios. The third and the fourth pieces of equation (22) are both private information, but it is the third piece of equation (22) that is the demand arising from information received from private signals of the investors. This third piece is naturally missing in uninformed investor‘s demand since they do not receive private signals. The fourth term, similar to the last term in the uninformed investors‘ case, is equal to the average hedge demand in the economy scaled by the percentage of informed investors in the market.

3.6. Change in currency demand of investors

Using equations (20) and (22), it is possible to express the change in currency demand of both types of investors in terms of shocks to the economy. First, I rewrite equation (20) as

$$B_i^m = \int_0^1 B_i^m \, di = \frac{\omega}{1 + z} \frac{z_i}{d_i \sigma^2_i} \frac{\phi \beta^2}{\gamma \sigma^2_i} - \omega b_t$$

$$+ \left( - \lambda_u u_t - \lambda_z z_t + \lambda_b b_t \right) \left( \frac{1 + z}{\gamma \sigma^2_i} \right) \left[ \omega - 1 + \phi \left( \frac{1 + \beta^*}{\beta^2} \right) \right]$$

using $B_i^m$ to indicate total currency demand of uninformed investors. After gathering the coefficients of the equation together, it is possible to represent the hedge demand, public signal, and future fundamentals in terms of error terms:

$$B_i^m = \left( \text{coef}^{un} \lambda_z + \frac{\omega}{1 + z} \frac{\phi \beta^2}{\gamma \sigma^2_i} \right) c_t^i + \left( \lambda_u \text{coef}^{un} - \omega \right) c_t^h$$

$$+ \left[ \left( \text{coef}^{un} \lambda_z + \frac{\omega}{1 + z} \frac{\phi \beta^2}{\gamma \sigma^2_i} \right) + \lambda_u \text{coef}^{un} \right] c_{t+1}^f$$

where

$$\text{coef}^{un} = \left( \frac{1 + z}{\gamma \sigma^2_i} \right) \left[ \omega - 1 + \phi \left( \frac{1 + \beta^*}{\beta^2} \right) \right]$$

In the same manner, the aggregate bond demand for informed investors can also be represented in terms of error terms:

$$B_i^m = \int_0^1 B_i^m \, di = \left( \text{coef}^{un} \lambda_z + \frac{1 - \omega}{1 + z} \frac{\phi \beta^2}{\gamma \sigma^2_i} \right) c_t^i + \left( \lambda_u \text{coef}^{un} - (1 - \omega) \right) c_t^h$$

$$+ \left[ \left( \text{coef}^{un} \lambda_z + \frac{1 - \omega}{1 + z} \frac{\phi \beta^2}{\gamma \sigma^2_i} \right) + 1 - \omega \right] \frac{\phi \beta^2}{1 + z} + \lambda_u \text{coef}^{un} \right] c_{t+1}^f$$
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where

\[ \text{coef}^m = \left( \frac{1 + \alpha}{\alpha} \frac{1}{\gamma\sigma_l^2} \right) \left[ 1 - \omega - \frac{\beta^e}{\beta_l} \right] \]

and \( B_{tot} \) represents total currency demand of informed investors. This representation permits the analysis of individual shocks and their affect on the contemporaneous currency demand by investors. Under the assumptions that the standard deviations of error terms are equal to 0.1 and, \( \alpha = 10, \gamma = 50, \) and \( T = 1, \) the coefficient of \( c_i^* \) is equal to 0.1806 for uninformed investors and \(-0.1806\) for informed investors. For uninformed investors, the coefficient of \( c_{i+1}^* \) becomes \(-0.050\) and the same coefficient becomes \(0.050\) for informed investors. Finally, the coefficient of \( c_i^* \) is \(-0.3922\) for uninformed investors and \(0.3922\) for informed investors. These coefficients inform us about how individual shock affects the currency demand of different investors in the model. For example, a positive shock to future fundamentals causes an increase in the aggregate bond demand of informed investors. A similar shock causes a decrease in that of uninformed investors. On the other hand, a shock to public signal increases aggregate bond demand of uninformed investors. To find the correlation for each shock, I set all the other shocks equal to zero and single out the effect of each one in that manner. For the public signal, the correlation becomes

\[ \text{corr} \left( \lambda_z \Delta e_t^*, \left( \text{coef}^m \lambda_z + \frac{\omega}{1 + \alpha} \frac{\beta^e}{\beta_l} \Delta e_t^* \right) \right) = \frac{2\lambda_z \left( \text{coef}^m \lambda_z + \frac{\omega}{1 + \alpha} \frac{\beta^e}{\beta_l} \right) \sigma_z^2}{\sqrt{\text{var}(\Delta B_{tot}^m)\text{var}(\Delta s_t)}} \]

which is equal to 0.0545 under the parametrization reported above. A similar correlation for hedge demand shock is equal to 0.2826 and the correlation for future fundamental shock is equal to \(-0.4353\). The correlation coefficient between the change in the exchange rate and the change in aggregate bond demand of uninformed investors is \(-0.2613\).

Conducting a similar analysis for the informed investor, I arrive at the following values for contributions of the public signal, hedge demand, and future fundamental shocks, respectively, to the correlation: \(-0.0540\), \(-0.2826\), \(0.4353\). The correlation coefficient with all shocks is 0.2613 for informed investors’ holdings.

When I analyse the correlation of a change in currency demand with a change in exchange rates, a positive shock to future fundamentals results in a positive correlation between change in currency demand for informed investors and the exchange rate. That correlation is negative and of the same magnitude for uninformed investors. This suggests that when there is a positive shock to future fundamentals, informed investors will increase their currency demand and uninformed investors will be the suppliers, offering evidence for the explanation of why financial investors are said to ‘push’ the market (Bjønnes et al., 2004). Better future fundamentals also cause the exchange rate to appreciate, which is consistent with stylized facts from the literature.

When the error term of the public signal is positive, uninformed investors take some of that change for increase in future fundamentals and their currency holdings increase. Since informed investors do not see a change in future fundamentals through their private signal, they have a more precise belief that true value of future fundamentals is not changing and they would be willing to sell currency to uninformed investors. Similarly, a positive shock to hedging demand in the economy is more likely to be mistaken by uninformed investors as an increase in future fundamentals so they would increase their currency holdings. Since informed investors have a more precise estimate about future fundamentals, they would be willing to sell currency in the market believing that the signal they saw can be attributed to the change in average hedging demand rather than future fundamentals.

When none of the shocks are set to zero, a positive correlation of 0.2613 is observed between the change in exchange rate and the change in currency holdings of informed investors. The results suggest that the effect of future fundamentals' shocks dominates the effect of other shocks in overall correlation calculations and this is primarily due to the coefficient of future fundamentals in the equilibrium exchange rate dominating other coefficients. Similarly, this causes a negative overall correlation between the change in exchange rate and the currency holdings of uninformed investors. The magnitude of correlations reported here are close to empirical observations from the Israeli foreign exchange market discussed in Section 4.

4. EMPIRICAL ANALYSIS

The theoretical model and calibration analysis presented above generates some results that are empirically testable with disaggregated customer order flow data. In line with the assumptions of the theoretical model, the investors in this data set are categorized into informed and uninformed groups. I use this customer order flow data to examine the correlation between a change in the exchange rate and the change in currency holdings of investors for both informed and uninformed investors. Moreover, this paper is the first study of disaggregated customer order flow data from the Israeli currency market.

4.1. Data

The data set I examine comes from the Foreign Currency Department of the Bank of Israel (BOI). It covers all daily spot and swap transactions in the New Israeli Sheqel (NIS)/Dollar market between June 2000 and June 2006. BOI collects data from certain banks regarding their daily trades of foreign currency with customers as well as with other banks. The data include spot and swap transactions by customers against the bank, but not forward transactions even though there is a perfectly functioning market for that in Israel.

According to the BOI's yearly publication analysing the developments in Israel's currency markets (Bank of Israel, 2002–2004), NIS trade against the dollar is the biggest part of total turnover in the NIS foreign exchange market, accounting for 87–90 per cent of total turnover over the last five years. In terms of the importance of the market, Israel's foreign exchange activity is comparable to that of countries such as the Czech Republic, Greece, and New Zealand. In 2004, average daily turnover was approximately $1.65 billion for the whole market, just below the 2003 figure of $1.68 billion. In terms of just the spot market, turnover was $722 million in 2004, slightly lower than the $748 million figure in 2003. Foreign currency is traded against the sheqel between the banks and their customers in Israel and abroad, and among the banks themselves in the interbank market. The current exchange rate policy is based on a free float of the sheqel vis-a-vis other currencies, and for many years the BOI pursued a policy of non-intervention in the foreign exchange market.

Customer order flow in the data is classified into three categories: foreign financial institutions, other customers, and domestic interbank. The foreign financial institutions classification includes foreign banks (commercial or investment) with branches in Israel. BOI notes that foreign financial institutions drive the market and engage in more speculative activity than do domestic customers (Bank of Israel, 2002–2004). On days of high trade turnover, the market share of foreign financials increases significantly compared with their average market share for each year. It is also noteworthy that foreign financial institutions consistently hold larger open foreign exchange positions (both long and short) than the Israeli customers. Based on this information from BOI, I hypothesize that foreign financial institutions are the customers who are driving the market, similar to financial customers in Bjonnes et al. (2005), and that they are the customers with speculative motives.

The second category of investor in the market, other customers, is a heterogeneous group of domestic customers who trade foreign exchange for variety of reasons such as imports and exports, tourism, fund
management, and investment. Inquiry into this group of investors with the head of the Economic Unit at BOI yielded a description of this group as domestic companies and private customers; by definition, non-financial domestic institutions. For the current analysis, I take this group of other customers to be similar to non-financial customers in Bjonnes et al. (2005).

Domestic banks are the intraday liquidity providers and the domestic interbank category of customer order flow covers trades between these banks. Purchase and sale data for the domestic interbank transactions sum to zero most of the time. Looking at the transactions between domestic banks and customers, the net currency holdings of customers do not sum to zero at the end of every day. The simple correlation between net currency holdings of these two types of customers in the data is approximately $-0.5$, suggesting that either banks hold some balances overnight or the BOI data do not cover the entire market. The latter explanation is more likely since I observe only the NIS/Dollar market data and it is very likely that banks can balance their overnight inventories through trading in different currency pairs as well.

4.2. Preliminary analysis

Table 1 presents descriptive statistics for the order flow data in the NIS/Dollar market spanning the whole time series. Moments are quite balanced for both of the customer types. Foreign financial institutions lead in buying NIS, whereas other customers lead in buying dollars. Standard deviations also seem to be similar with average daily total turnover reaching $570 million. Total turnover average is higher (approximately $630 million) when early years in the data set are omitted since those are the years when the market was still maturing. BOI reports indicate that the market matured in 2002 after several years of expansion in response to liberalization (Bank of Israel, 2002–2004).

Before examining the data graphically, I calculate simple correlations between the change in exchange rate and the change in currency holdings of different investors. Recent literature using other data sets indicates a positive correlation between financial customer order flow and the change in exchange rate and a negative correlation between the non-financial customer order flow and the change in exchange rate. This negative correlation associated with non-financial customers is used to identify them as overnight liquidity suppliers. In the Israel data, this corresponds to the other customers category and I test whether they are the ones supplying the liquidity in the overnight market. The positive correlation associated with the foreign financials identifies them as ‘pushers’ in the market; they are the speculators who initiate the trade. As expected, the correlation between the change in currency holdings of foreign financial customers and the change in exchange rate is $0.12$. The corresponding correlation for the other customers category is $-0.22$. The magnitude of these correlation numbers increases for different segments of the data, but the signs of the correlation coefficients always stay positive for foreign financials and negative for other customers, which is consistent with the literature.

I graph the daily data to see how net purchases of the customer groups and the exchange rate move together in the NIS/Dollar market. Figures 4–6 are graphs of cumulative net order flows of customers and the exchange rate for various periods. Disaggregating the data into three periods helps to demonstrate how Israel’s currency market matures over time.

| Table 1. Descriptive statistics: currency flows in spot market |
|-------------------------------------------|----------------|----------------|
| Variables | Order flow        | Total turnover |
| Financial   | Other customers  | Aggregate  |
| Mean        | $-3.18$         | $-2.67$     | $-5.85$      | $574.67$       |
| Std. dev.   | $57.42$         | $67.06$     | $62.08$      | $272.24$       |
| Minimum     | $-335.22$       | $-262.79$   | $-256.92$    | $93.32$        |
| Maximum     | $255.70$        | $438.31$    | $307.61$     | $2164.61$      |

Note: All values are in millions of dollars.
Figure 4 graphs the flows corresponding to 2000 and 2001. The market was still growing during those years and foreign investors were slowly coming into the currency market in Israel. The growth rate in the market was 54 per cent in 2000 and 58 per cent in 2001. This indicates that the market may not be in equilibrium during those years. During this time period, foreign financials appear to be buying currency while the dollar is appreciating, whereas other customers are doing the selling. Still, the exchange rate appears to be much more volatile than the net flows in the market and that could be another sign of market immaturity. As a result, I analyse this early time period separately in the remainder of the paper.

Figure 5 presents the flows from 2002 to 2003. The most noticeable feature of this graph is that flows from foreign financials are negatively correlated with the flows from other customers. Because the market may still be maturing in 2002, a better correlation is observed between the flows and the exchange rate in 2003. The order flow from foreign financials appears to be positively correlated with the change in the exchange rate, whereas order flow from the other customer group is negatively correlated. The correlation coefficient between exchange rate changes and the flows from foreign financials is 0.16 for the 2002–2003 period and it increases to 0.27 when only 2003 data are considered. On the other hand, the correlation coefficient between exchange rate changes and the flows from other customers is −0.3 for the same period.

Figure 6 looks at the most recent years of data, 2004–2006. A clear negative correlation between the net holdings of other customers and the change in exchange rate is evident in the graph. Even though foreign financials appear to be in a selling trend in the market in the latter part of the time series, high-frequency changes in net holdings are still positively correlated with changes in exchange rate.
4.3. Empirical model and results

I employ a simple regression model to examine the empirical relationship between order flows and changes in exchange rate. The dependent variable is the change in the log of the spot exchange rate and the independent variables are disaggregated order flows by different customer types. If order flow from different customer types is correlated differently with price due to private information, these effects should be observable in a simple regression. To test this hypothesis, I run the following regression on the disaggregated data, where financial and other customer net order flow is separated into distinct independent variables:

\[ \Delta s_t = \beta_0 + \beta_1 x_{t}^{\text{fin}} + \beta_2 x_{t}^{\text{other}} + \epsilon_t \]  

(26)

Table 2 summarizes the results from running the regression in equation (26) on daily disaggregated data. Similar to what the theoretical model suggests, order flow from foreign financials is positively associated with the change in the exchange rate, whereas other customers’ net order flow is negatively correlated. All coefficients are statistically significant with the exception of the coefficient on foreign financials for the 2000–2001 period. This may be because participation by foreign financials in Israel’s currency market was still growing during those years and the market itself was still maturing. \( R^2 \) statistics suggest that approximately 8 per cent of daily changes in the exchange rate can be explained by daily disaggregated net order flow from customers.

Next, I run the regression above using a lower-frequency data. Lyons (2001) reports a better fit for a similar regression model in monthly frequency rather than daily, which is consistent with what I find here. Table 3 summarizes the regression in equation (26) for weekly and monthly data during the 2003–2006 period. Finally, I include a macroeconomic variable in this regression, the interest rate differential between the US and Israel. Theoretical model shows that current fundamentals are an important part of equilibrium exchange rate and without a proxy for fundamentals in the regression, there is room for omitted variable bias. I choose the interest rate differential as a proxy for macroeconomic effects since it is known to be highly correlated with exchange rates in the long-run and it is easily available at any required frequency.

Lowering the frequency of the data to weekly intervals improves the \( R^2 \) statistic to approximately 17 per cent. The signs on the coefficients are the same as in the higher-frequency regression and they are both statistically significant. The results suggest that a one million more dollar purchase than sales by foreign financials is associated with an increase of 0.048 per cent in the NIS/Dollar rate over a one week period. The magnitude of an average weekly net purchase is approximately $30 million for foreign financials, thus in a normal week, order flow from foreign financials may be associated with a 1.5 per cent change in the exchange rate. As expected, this coefficient is large compared with other currency markets but the NIS/Dollar is more of a local market and it is not as liquid as markets for more popular currency pairs (e.g. Sheqel/Dollar exchange rate, 2004–2006).
A similar net flow from other customers is correlated with a fall in the exchange rate of 0.038 per cent over a one week period.

The monthly order flow regression in Table 3 returns an even better fit with an $R^2$ of 30 per cent. The model fit improves to 40 per cent when I include the interest differential between countries as an additional explanatory variable. The coefficients are similar; a one million dollar larger purchase than sales by foreign financials is associated with a 0.060 per cent increase in the NIS/Dollar rate over a one month period. As before, the correlation between a similar net flow from other customers and the fall in exchange rate is around 0.046 per cent.

A brief discussion is in order about the possibility of multicollinearity in the explanatory variables. It is important to understand how much the correlation between the disaggregated order flows affects the regression results. Even though the correlation coefficient between the order flow of foreign financial institutions and other customers is not trivial (approximately $-0.50$), adding each of the variables to the regression changes neither the coefficients nor the significance of single variable regressions by much. One way to detect multicollinearity is to run the regression of change in exchange rate on the two-order flow variables independently and compare the coefficients of those regressions with the multivariate regression.
If multicollinearity is particularly problematic, coefficients would lose statistical significance. In the current analysis, however, the coefficients of multivariate regressions are still significant. The empirical results from the Israeli foreign exchange market are consistent with other findings in the literature. Marsh and O’Rourke (2005) report that a net flow of one billion Euros from leveraged financial institutions is associated with a 1.49 per cent rise in the value of Euro over one day, and a 1.86 per cent rise over a week. A similar flow from non-financial corporations is associated with a fall in the value of the Euro of 0.68 per cent over one day and a 0.93 per cent increase over a week. Lyons (2001) reports that a similar net flow from leveraged funds is associated with a 0.6 per cent appreciation of the Euro over a one month period.

This analysis suggests that orders from different types of customers are correlated differently with the change in exchange rate. In addition, the consistent pattern of coefficients observed in a variety of empirical studies suggests that there is important information contained in customer order flows. If the correlation between flows and changes in the exchange rate was simply due to liquidity effects, then there would be no difference between equally sized orders from different customer types. The results reported here, as well as those from the literature, suggest that there is a difference. Another similar pattern observed in the literature is that trades from financial customers have a larger price impact than others. The common view in the literature is that this is due to superior information possessed by the financial investors in the market.

5. CONCLUSION

In this paper, I offer both a theoretical and an empirical examination of the information asymmetry among investors in the foreign exchange market and the relationship between customer order flow and exchange rates. The theoretical model incorporates macroeconomic fundamentals, a microstructure approach, and hierarchical informational asymmetry. Investment decisions of asymmetrically informed investors generate and explain the commonly observed correlations between currency holdings and the exchange rate in the foreign exchange market. While other researchers have documented these correlations empirically, this paper also offers a theoretical model that explains the mechanics behind the empirical relationships. Additionally, I couple the theoretical model with empirical results from a market that has not been studied before in terms of the microstructure approach to foreign exchange markets.

The primary findings of the theoretical model indicate that the amount of asymmetric information in the market plays an important role in determining the equilibrium exchange rate. This asymmetric information between investors also assigns informed investors the role of market ‘pushers’ and less well-informed investors the role of liquidity suppliers. In a general analysis, changes in the exchange rate and currency demand are positively correlated for well-informed investors and negatively correlated for less well-informed investors. One scenario is that informed investors, after observing through their private signals that future fundamentals will be higher, increase their demand for foreign currency and thus drive up the exchange rate. This increased exchange rate leads the less well-informed investors to sell their currency holdings, creating a negative correlation between their holdings of currency and the equilibrium exchange rate.

The theoretical results are supported by the empirical analysis. The correlation between the change in currency holdings of informed investors and the change in the exchange rate is 0.12 in the BOI data set and 0.2613 in the theoretical model. The corresponding correlation for uninformed investors is −0.22 in the data set and −0.2613 in the theoretical model. Although the magnitude of these correlations differ, the model predictions better match the empirical correlations when the matured years of the Israeli foreign exchange market are analysed. These results offer a strong theoretical and empirical basis for believing that the characteristics of the investors holding currency matters a great deal in foreign exchange markets.

Finally, the empirical analysis indicates that a one million dollar larger purchase than sales by foreign financials is associated with a 0.060 per cent increase in the NIS/Dollar exchange rate over a one month period and a similar net flow from other customers is associated with a 0.046 per cent fall in the exchange
rate. I also find that disaggregated order flow data and interest rate differentials explain 40 per cent of the change in exchange rates at monthly frequencies.

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NOTES

1. This model introduces hierarchical information asymmetry and builds upon the model presented in Bacchetta and Van Wincoop (2006).
2. The fact that \( z_t \) has a persistent term permits the public signal to be expressed in terms of its current and past innovations when conjecturing the equilibrium exchange rate.
3. This is same as assuming \( p_b = 0, w^*_t = r_t^* \) and \( f_t = e_t^* \). In addition, since the model is solved for an equilibrium value of the conditional variance of next period’s exchange rate, I drop the time subscript on \( s^2_t \) from this point forward.
4. These graphs are drawn under the following assumptions: \( T = 1, p_b = 0, w^*_t = 0, f_t = e_t^* \). In addition, I set \( \alpha = 10, \gamma = 50 \) and all standard deviations of shocks are equal to 0.1.
5. These theoretical results are similar to the findings of Wang (1993), who argues that the limiting equilibrium of \( \omega \rightarrow 1 \) can be very different from the equilibrium when \( \omega = 1 \).
6. These values are chosen to match those used in Bacchetta and Van Wincoop (2006).
7. Unfortunately, I do not know what percentage of the total market is composed of these reported trades.
8. These figures include swaps as well as spot transactions.
9. The figures show the cumulative flow of foreign financials, other customers, and the NIS/Dollar exchange rate for different time spans. The spot exchange rate is expressed on the right-hand scale. The cumulative customer flow is expressed on the left-hand scale in millions of dollars. Horizontal axis shows the number of days corresponding to the chosen time period.
10. Marsh and O’Rourke (2005) also report that flow in other markets may have much higher coefficients. A similar net flow in the Euro/Yen market, for example, is associated with a 4 per cent increase in the Euro.

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